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B69,03065

SUBJECT: ATM Thermal Control System
Case 620

DATE: March 18, 1969

FROM: J. Gillespie

ABSTRACT

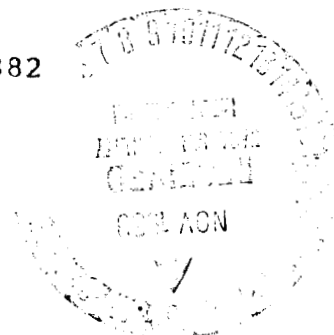
The ATM thermal control system consists of both an active and a passive system. The rack-mounted components, such as batteries, are passively controlled; the experiment canister is actively controlled by a single loop fluid system, with methanol/water (80/20) as the coolant. Both standoff and integral heaters are used with the experiments to prevent thermal gradients. The experiment requirements and thermal control system are discussed.

(NASA-CR-106703) ATM THERMAL CONTROL SYSTEM
(Bellcomm, Inc.) 17 p

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MEMORANDUM FOR FILE

INTRODUCTION

The ATM consists of a canister, which contains the ATM experiments, mounted on gimbals in an outer rack structure as shown in Figure 1. The experiments are mounted on the spar within the canister, and the spar is thermally isolated from the experiments and canister with insulation and low conducting experiment mounts. The canister is thermally controlled by an active system and the rack is thermally controlled by a passive system, supplemented by heaters where required. Initially, the thermal control system for the canister was a passive system. However, by November 1967, the need for an active system to support experiment requirements was established; and, by January 1968, an active system was selected. A combination of standoff and integral heaters is used with the experiments within the canister. The experiment requirements, thermal control system, and thermal problems are discussed in the following sections.

EXPERIMENT REQUIREMENTS

Thermal distortion due to thermal gradients must be minimized during exposure time. The standoff and integral heaters associated with the experiments prevent local coldspots, thus providing a uniform temperature. The experiment heater concepts are shown in Figure 2. The active cooling system maintains the canister wall temperature at 47-58°F to assure proper experiment operating temperature. The spar is wrapped with ten layers of aluminized mylar insulation and its temperature is approximately 62°F. Typical values of heater temperatures are shown. The heater capacities are approximately 10-40 watts each. Current experimental thermal requirements are shown in Table I. (1)

From the time that the ATM leaves the clean room until it is launched, the experiment package is purged with clean, dry air and/or nitrogen (H_2O content of 50 ppm maximum)

at a temperature of $75 \pm 5^\circ\text{F}$. A nominal positive pressure of 1 to 2 inches of water (.036 to .072 psi) is maintained in the experiment package throughout this period. The maximum positive pressure in the package will be approximately 3 inches of water (.1 psi).

RACK THERMAL CONTROL SYSTEM

Rack-mounted ATM components, such as batteries, electronics, and control moment gyros are passively controlled through the application of proper thermal coatings and insulation, and positioning with respect to heat sinks and sources. White paint ($\epsilon = .9$, $\alpha = .2$) is used on the thermal covers, batteries, control moment gyros, and the top of rack components. Allowance is made for degradation of the solar absorptivity (α) from .2 to .5.* An aluminum solar shield, also painted white, is mounted on the sun end of the rack to prevent direct solar impingement on rack-mounted components. Auxiliary electric heaters are used on the three control moment gyros. Each control moment gyro has two 120 watt heaters and two 24 watt heaters; one heater of each size per bearing. The 120 watt heaters are used initially to bring the bearing temperature to 40°F and if the bearing temperature falls below 40°F . The 24 watt heaters are used if the bearing temperature falls below 60°F . Additional heaters may be required in other components such as batteries and the star tracker. Component operational temperature limits and calculated maximum and minimum temperatures are shown in Table II. (1)

Previous analysis indicated that the Charger Battery Regulator Modules (CBRM's) mounted on the rack would experience temperatures above design limits. Insulation has been removed between the modules and the rack to improve radiation characteristics. The latest analysis (1) indicates that temperatures for the hottest case are within design limitations. The results of the analysis are shown in Table III.

Because of an increase in size of electrical components, electrical cabling has been rerouted on the Rack. This will require relocation of many of the rack components, but should result in more optimum temperatures for components that are presently marginal. (Refer to Table II for marginal rack components.)

* Private communication S. Levine, September 10, 1968.

TABLE I

ATM EXPERIMENT REQUIREMENTS PERTINENT TO THERMAL CONTROL

Experiment	Pointing Stability (Arc Sec)	Exposure Time (Min)	Exper. Power (Watts)					Operating Temperature (°F)	Type Heater Required
			Avg. Elec.	Solar Minus Rerad.		Avg. Total			
				Max	Avg				
GSFC	± 2-1/2	1.6	20	40	29	49	70	Integral	
AS & E	± 2-1/2	5.0	48	35	25	73	70	Integral	
HCO-A (MOD)	± 2-1/2	15.0	54	28	20	74	70	Standoff	
HAO	± 5	16.0	15	14	10	25	70	Standoff	
NRL-A	± 2-1/2	5.0	25	4	3	28	70	Standoff	
NRL-B & XUV	± 2-1/2	15.0	44	4	3	47	70	Standoff	
H #1	± 2-1/2	<<1.0	11	1.4	1	12	50 - 70	None	
H #2	± 2-1/2	<<1.0	8	1.4	1	9	50 - 70	None	
						317			

Solar Sensor and Rate Gyros Dissipation = 33 Watts.

Some Rack components, such as batteries and the star tracker, will require heat prior to activation of the ATM. Timelines are required for electrical components prior to this time to determine heat dissipated so that heater sizes and system power requirements can be determined. It is also necessary to determine how much electrical power is available for heaters prior to activation in the solar inertial mode.

CANISTER ACTIVE THERMAL CONTROL SYSTEM

A single loop cooling system⁽²⁾ is used to control the operating temperature of the canister-mounted experiments. The interior canister wall is part of the active thermal control system (TCS) and absorbs the heat generated by the experiments and control system components. The heat is transferred to the space radiator, where it is rejected to the space environment. The space radiator is mounted circumferentially around the exterior of the sun end of the canister. Other TCS components, such as the pump package, modulating flow control valve, electronic control packages, heater, etc., are attached to the outside of the canister. The components of the active TCS and their quantity, source, and previous application are listed in Table IV. Total approximate weight of the active TCS is 488 lbs.

Pump Package

A schematic diagram of the TCS is shown in Figure 3. A modified CSM pump, with an improved impeller, provides the motive force in the coolant loop and provides a nominal flow rate of 850 lbs of coolant per hour. The primary pump is backed up by a standby pump. An accumulator with 379 cubic inches of useable volume provides fluid for system leakage and fluid thermal contraction and volume for fluid thermal expansion.

Modulating Flow Control Valve

The modulating flow control valve directs the coolant fluid through either the space radiator or through the bypass to maintain a constant fixed fluid temperature of $50 \pm 3^{\circ}\text{F}$ at the inlet of the cold panels. Control is provided by means of a temperature sensor and control electronics

TABLE II
MAXIMUM AND MINIMUM COMPONENT TEMPERATURES
OPERATIONAL CASE

ZONE	COMPONENT	LINE NO.	POWER (WATTS)	TEMPERATURE LIMITS (°F)		T _{MAX} (°F)	T _{MIN} (°F)
10	CMG INVERTER	6	69.2	158	-58	97	-22
	MAIN POWER DISTRIBUTOR	71	50	147	-40	131	-29
	AUXILIARY POWER DISTRIBUTOR	73	50	147	-40	127	-32
11	CONTROL COMPUTER SECTION "A"	32	22.5-M	165	-67	98	-16
			24.9-D				
	CONTROL COMPUTER SECTION "B"		66.2-M	165	-67	103	-18
			85.5-D				
	CONTROL COMPUTER SECTION "C"		11.4-M	165	-67	96	-25
			14.7-D				
13	CONTROL COMPUTER SECTION "A"	33	0	165	-67	62	-57
	CONTROL COMPUTER SECTION "B"		0	165	-67	63	-60
	CONTROL COMPUTER SECTION "C"		0	165	-67	62	-59
14	CMG INVERTER	4	69.2	158	-58	82	-20
	CMG INVERTER	5	69.2	158	-58	82	-20
16	ATM DIGITAL COMPUTER AND INPUT/OUTPUT ASSEMBLY	34435	150	165	-15	104	-33
18	POWER TRANSFER DISTRIBUTOR	72	71	147	-40	65	-36
	FINE SUN SENSOR CONDITIONER	9	2.4	158	-58	60	-21
	CONTROL DISTRIBUTOR NO. 2	65	30	147	-40	98	-9
	CONTROL DISTRIBUTOR	66	15	147	-40	77	-17
	TRANSFER ASSEMBLY	74	5	167	-67	60	-18
	C&D LOGIC DISTRIBUTOR	90	40	167	-67	97	-19
	SWITCH SELECTOR MODULE II	95	2	212	-13	58	-17
	MEASURING RACK*	115	12	122	-4	65	-10
	REMOTE ANALOG SUBMULTIPLEXER	116	3	122	-4	53	-27
	REMOTE ANALOG SUBMULTIPLEXER	117	3	122	-4	55	-24
	AMPLIFIER & SWITCH ASSEMBLY	133	20	122	-40	79	-17
	DIRECTIONAL COUPLER	142	0	167	-40	49	-41
	VSWR MEASURING ASSEMBLY	143	0.2	167	-40	79	-41
	COAXIAL SWITCH	144	0	167	-40	48	-41
19	REMOTE ANALOG SUBMULTIPLEXER COVER	118	3	122	-4	53	-24
		-	-	-	-	53	-65
	CONTROL DISTRIBUTOR NO. 5	75	15	147	-40	56	-46
	SIGNAL CONDITIONING RACK	109	3	122	-4	42	-58
	SIGNAL CONDITIONING RACK	110	3	122	-4	40	-62
	SIGNAL CONDITIONING RACK	111	3	122	-4	43	-59
	SIGNAL CONDITIONING RACK	112	3	122	-4	42	-59
	SIGNAL CONDITIONING RACK	113	3	122	-4	37	-65
	REMOTE ANALOG SUBMULTIPLEXER	119	3	122	-4	37	-65
	REMOTE ANALOG SUBMULTIPLEXER	120	3	122	-4	36	-66
	MULTIPLEXER ASSEMBLY	123	4.8	122	-4	48	-56
	MULTIPLEXER ASSEMBLY	122	4.8	122	-4	56	-52
	LM END COVER	-	-	-	-	67	-38
	SUN END COVER	-	-	-	-	60	-107
22	MEASURING VOLTAGE SUPPLY	36	7	165	-40	76	4
	MVS REDUNDANT	37	7	165	-40	64	-8
	NRL-A POWER SUPPLY	41	2.6	158	-40	58	-15
	NRL-B POWER SUPPLY	42	2.6	156	-40	60	-13
	J-BOX ASSEMBLY	77	0	167	-67	44	-31
	SWITCH SELECTOR MODULE II	94	2	212	-13	60	-6
	SWITCH SELECTOR MODULE II	96	2	212	-13	56	-10
	SWITCH SELECTOR MODULE II	97	2	212	-13	57	-8
	SWITCH SELECTOR MODULE II	98	2	212	-13	57	-8
	COMMAND RECEIVER	126	3.8	185	-40	79	-17
	PCM/DDAS ASSEMBLY - ACTIVEZ	131	35	122	-4	122	27
	PCM/DDAS REDUNDANT	132	0	122	-4	37	-36
	COMPUTER INTERFACE UNIT	134	12	122	-4	64	-7
	ASAP INTERFACE UNIT	135	8	122	-4	60	-14
	MEMORY MODULE	136	7	122	-4	56	-22
	TAPE RECORDER - ACTIVE	138	11	104	32	92	17
	TAPE RECORDER - REDUNDANT	139	0	104	32	58	-18
	DC - DC CONVERTER	140	31	122	-4	103	26
	MAIN ELECTRONICS ASSEMBLY	169	41	165	-16	47	-27
	SUBCOMPUTATOR ASSEMBLY	170	3.4	165	-16	82	-5
	COVER	-	-	-	-	55	-61
24	MEASURING DISTRIBUTOR NO. 3	70	20	167	-67	54	-27
	J-BOX ASSEMBLY	76	0	167	-67	40	-30
	SIGNAL CONDITIONING RACK	106	3	122	-4	38	-35
	SIGNAL CONDITIONING RACK	107	3	122	-4	41	-31
	SIGNAL CONDITIONING RACK	108	3	122	-4	37	-37
	SIGNAL CONDITIONING RACK	114	3	122	-4	37	-37
	MULTIPLEXER ASSEMBLY	121	5	122	-4	40	-33
	MULTIPLEXER ASSEMBLY	124	55	122	-4	38	-35
	REMOTE DIGITAL MULTIPLEXER	129	12	122	-4	56	-16
	REMOTE DIGITAL MULTIPLEXER	130	12	122	-4	56	-16
	COAXIAL SWITCH	147	0	167	-40	36	-37
	COMMAND DECODER	153	5.5	185	-40	53	-25
	LM END COVER	-	-	-	-	-	-55
	SUN END COVER	-	-	-	-	-	-55

*REPLACED BY REMOTE ANALOG SUBMULTIPLEXER

TABLE III
MAXIMUM CBR TEMPERATURES
ZONE 23

MODULE	MAXIMUM TEMPERATURES (°F)		
	CELLS	LID ELECTRONICS	INTERNAL ELECTRONICS
1	74.4	138.5	79.0
2	73.7	139.0	80.3
3	77.7	139.9	82.6
4	77.6	140.1	83.2
5	74.0	139.1	80.6
6	74.8	138.7	79.5

CELL UPPER LIMIT - 86°F
ELECTRONICS UPPER LIMIT - 149°F
ELECTRICAL POWER - 200 WATTS

MODULE DESIGNATION

6	5
4	3
2	1

TABLE IV

ATM THERMAL CONTROL SYSTEM COMPONENTS

<u>Component</u>	<u>Quantity</u>	<u>Source</u>	<u>Previous Application</u>
Accumulator Assembly Methanol/Water	1	New	N/A
Pump Package	1	AiResearch	CSM - Modified
Valve Assembly, Manually Operated	6	AiResearch	CSM
Cold Plates, Thermal Conditioning	16	MSFC	N/A
Radiator Panels	4	MSFC	N/A
Modulating Flow Control Valve	1	LTV	CSM
Modulating Flow Control Valve Sensor	1	LTV	CSM
Modulating Flow Control Valve Controller	1	LTV	CSM
Heater	1	LTV	CSM
Heater Controller	1	LTV	CSM
Heater Controller Sensor	1	LTV	CSM
Valve Assembly Check	1	AiResearch	CSM
Valve Assembly Flow Path Selector Electrical Pulse Operated	2	New	N/A

located at the inlet to the coldplates. The modulating flow control valve is redundant. The change from primary valve assembly to back-up valve assembly must be done manually from controls located in the LM-A. The flowpath selector valve blocks either the primary or redundant modulating control valve, depending on which is in operation.

Radiator

The heat absorbed by the cold panels is rejected into space by the radiator. The radiator is aluminum and is designed to reject 500 watts to space. Existing requirements are for approximately 317 watts to be rejected to space. A typical radiator panel is shown in Figure 4. The radiator is mounted on fiberglass stand-offs at the sun end of the canister. The coolant is routed sequentially through each of four radiator panels.

Heater

In the event the radiator environment is too cold to maintain proper cold panel inlet temperature, heat will be supplied to the coolant by an electric heater mounted in the radiator bypass line. The capacity of the heater is 500 watts. Step control of the two heating elements is accomplished automatically. Redundant heating elements, temperature sensors and heater controller circuitry are provided for backup in case of failure of the primary heating system.

Thermal Shield

The sun end of the canister serves as a thermal shield to prevent heat leaks into and out of the canister. Movable heat shield doors cover experiments and ATM pointing sensor apertures to protect from thermal effects and contamination. A lip at the sun end of the canister extends radially outward beyond the canister to prevent solar impingement between the rack-mounted solar shield and canister. The sun end of the canister is made of aluminum and is covered with two inches of high performance aluminized mylar insulation (NRC-2). The outside surface of the insulation is covered with aluminum, which is painted white ($\epsilon = .9$, $\alpha = .2$).

Cold Plates

The entire interior canister wall (except access doors) serves as a heat sink for the experiments and components. The wall is divided into sixteen cold panel sections, made of aluminum. Flow through each section is in parallel. A typical cold plate is shown in Figure 5. The cold plate exterior surfaces are covered with two inches of high performance aluminized mylar insulation (NRC-2). The outer layer of insulation is Tedlar ($\alpha = .9$, $\epsilon = .9$).

Coolant

Methanol/water (80/20) has been selected as the coolant for the active system. Coolants which were evaluated for usage on ATM are compared in Table V⁽³⁾. The desirable fluid properties for a coolant are low freezing point, high specific heat, high thermal conductivity, non-toxicity, low viscosity, and a moderate vapor pressure. Heat transfer rates of coolants are also strongly dependent on whether the flow regime is laminar or turbulent. The flow regime is mainly turbulent for the ATM fluid loop. Based on turbulent flow, the pumping power for methanol/water (80/20) is less than other coolants to maintain a given heat transfer rate.⁽⁴⁾ This property and others have made methanol/water (80/20) the most attractive choice for the coolant of the ATM active system.

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Attachments

Table V

ATM Fluid Comparison for Single Loop System

Fluid	Freezing Or Pour Point(°F)	Boiling Point (°F)	Required Flow Rate (lb/hr)	System Pressure Rise(psid)	Number of CSM Pumps Required	CSM Pumping Power (watts)
Glycol/Water (60/40)	- 63	237	790	38.4	4	180
Methanol/Water (80/20)	-154	158	842	22.8	1 modified	104
Freon E2	-190	214	2350	50.6	6	348
Freon 21	-211	48	2220	41.8	6	300
FC-75	- 80	214	2290	52.7	5	450
Coolanol-15	-140	415	1310	50.7	Not Available 5 (Gemini)	Not Available 645 (Gemini)

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References

1. "Preliminary Design Review of the Apollo Telescope Mount (ATM) Thermal Control Program," K. L. Mitchell/MSFC, NASA TM X-53809, January 2, 1969.
2. "Cluster Systems Description Document," Martin-Marietta Corporation, July 1968.
3. "ATM Status Report," Presented May 21, 1968.
4. "ATM Canister Active Control System Study," Martin-Marietta Corporation, November 29, 1967.

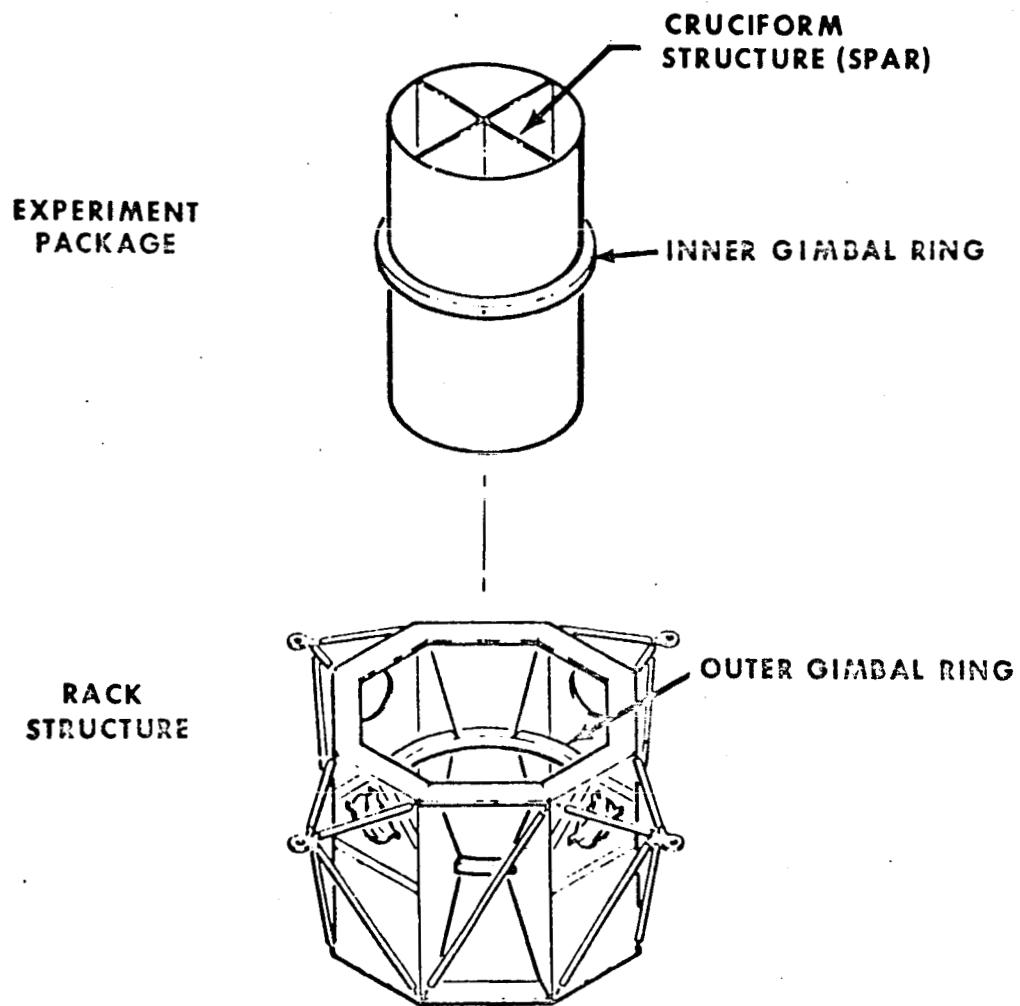


FIGURE 1 - ATM RACK AND EXPERIMENT PACKAGE

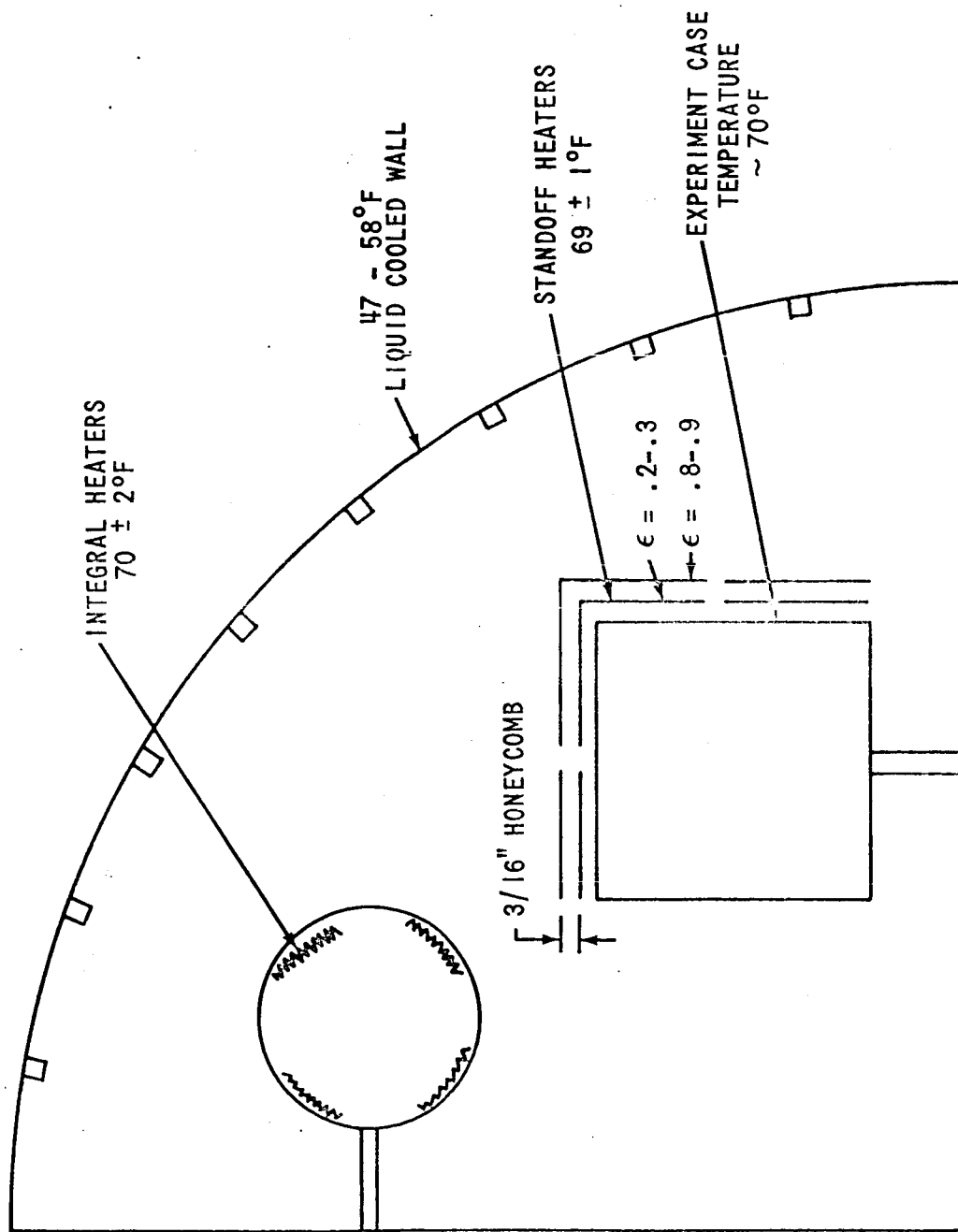


FIGURE 2 - EXPERIMENT HEATER CONCEPTS

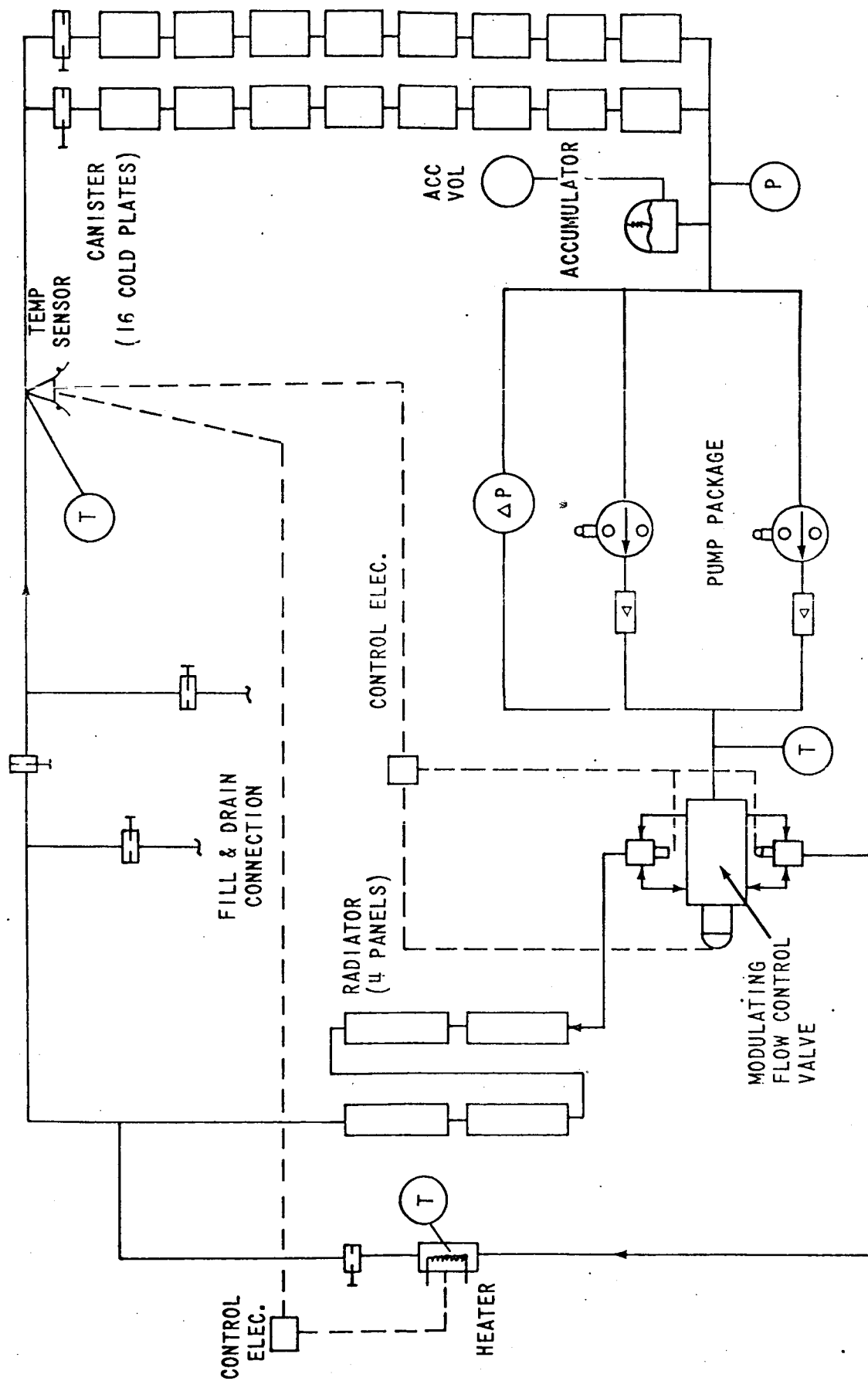
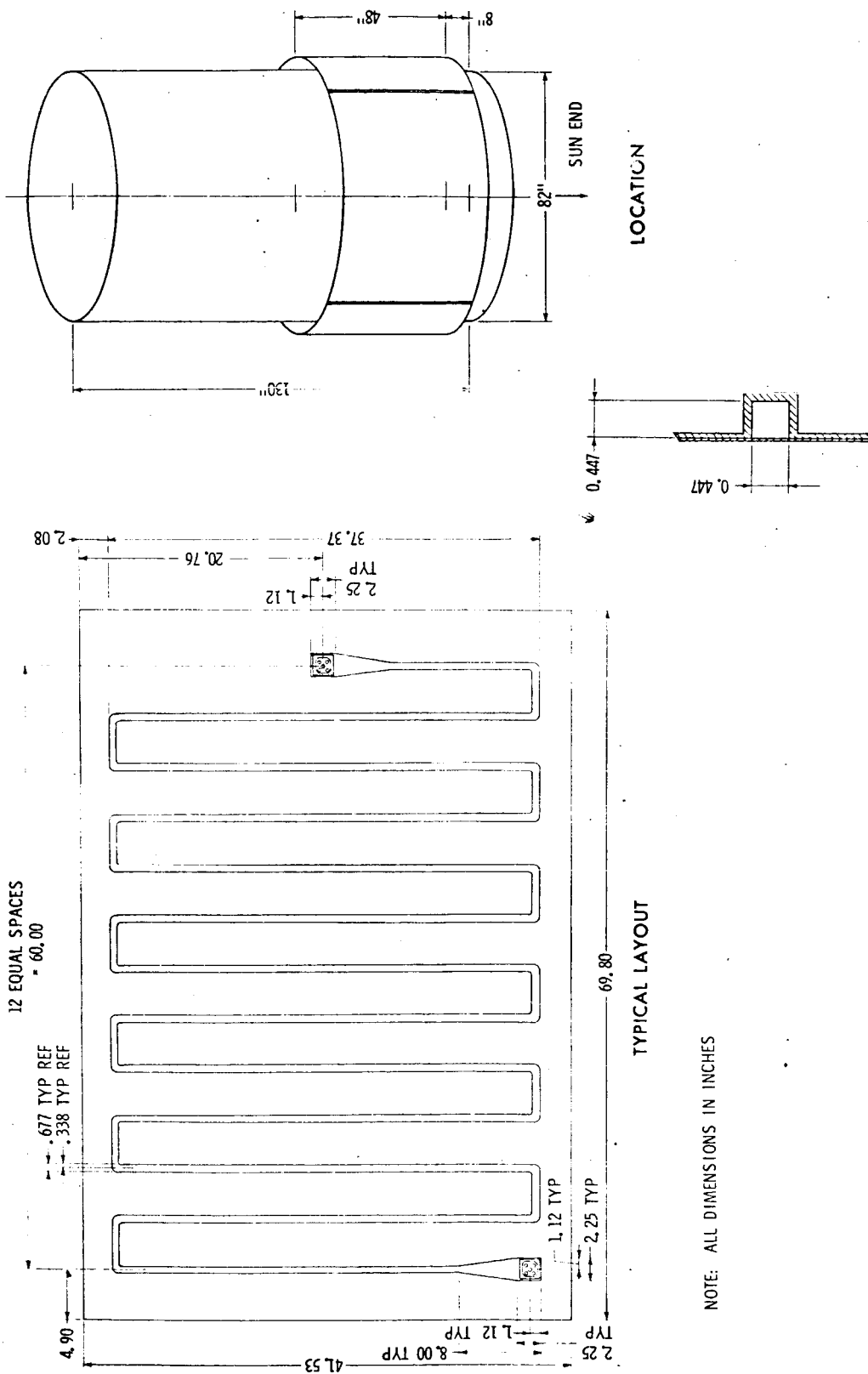


FIGURE 3 - ATM FLUID THERMAL CONTROL SYSTEM SCHEMATIC



CROSS SECTION

FIGURE 4 — ATM RADIATOR PANEL

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